Spring 2018

Integration of plastic recycling within a smaller community: Reducing Plastic Pollution in the Environment

Olivia Palenscar
SIT Study Abroad

Integration of plastic recycling within a smaller community: Reducing Plastic Pollution in the Environment

Olivia Palenscar
SIT: School for International Training
Iceland Greenland: Climate Change and the Arctic
Spring 2018

Abstract

The purpose of this research is to bring awareness to plastic pollution and find a way integrate plastic recycling workshops in a smaller community. Plastic pollution is a worldwide issue. Plastic is a versatile material and can be used to make almost anything, which is an attractive trait but the amount of plastic being consumed is alarming and only continues to increase. Plastic essentially never goes away because the degradation of plastic can last hundreds of years. The challenge is to find ways that everyone can recycle plastic because over 90% of plastic does not end up being recycled. Most plastic ends up in the marine or terrestrial environment and eventually breaks down in microplastics that inflict danger on species and can enter food chains. Interviews were conducted with a precious plastic organization member and educators for perspective on bringing this to an educational setting or small town community. The research has identified that it is possible to set up a small recycling workshop in a community. A workshop began to be set up in at the local high school in Ísafjörður, Iceland. There is still more developing to be done but the ground work has been laid. A plastic shredder was set up, plastic was collected and shredded, a mold was welded together, and plastic was melted down, and finally milled to create a final product. The final product was a lunchbox and represents how normal household plastic can be turned into something useful and it can reduce plastic usage in the future.

Acknowledgements

I would like to first thank Daniel Govoni for helping me through the semester and telling me that doing algae for my ISP was a bad idea. He helped me realize I should do something I am passionate about. Also thanks to Dan for listening to me talk to him about my life and about my frustrations with the project for at least an hour every week.

Another, thank you to my advisor Þórarinn Bjartur Breiðfjörð Gunnarsson for being super intrigued by what I wanted to do and helping me make it happen! I appreciate all of your hard work and curiosity for plastic pollution education. Also, he is the best photographer. The countless photos were a huge help. I cannot wait to come back and see what the plastic recycling workshop will look like!

A big shout out goes to International SOS for paying for all of my medical bills. Thanks to all the hospitals that gave me treatment and helped me through these hiccups in my health.

And one last thank you, the one that means the most is for my host family, I would like to thank them for making me feel so welcomed and loved. You made my time in Ísafjörður unforgettable. Study abroad would have not been the same.

Table of Contents

1. Introduction……………………………………………………………………………..5
2. Literature Review……………………………………………………………………......6
3. Methods…………………………………………………………………………………..16
4. Ethics……………………………………………………………………………………..28
5. Results…………………………………………………………………………........28
6. Discussion……….……………………………………………………………….........32
7. Conclusion…………………………………………………………………….............36
8. Bibliography……………………………………………………………..................37

1. Introduction

Ever since the 1960's when the plastic industry began to take off, plastic has been consumed worldwide at incredibility unsustainable rates. Plastic pollution is all around us because plastic is found everywhere and in everything. It is impacting the environment we live in and the species that live in it. It can even inhibit our own and will continue to on bigger scales as plastic usage continues to grow.

Plastic is inevitable but if we can begin the small scale recycling process in many different places, we could begin reducing plastic use drastically, and eliminate the plastic waste that ends up in our environments. The question I investigated through the duration of this research project was, how can plastic recycling be integrated within a smaller community? Specifically, for the realm and given timeframe of this project, I only looked at setting up a workshop in Ísafjörður, Iceland and at a small college in Claremont, California called Harvey Mudd College.

The objectives of this research project are:

- Spark interest in the community to reuse and recycle plastic
- Research and learn about the different kinds of plastics
- Learn how to build a small recycling workshop
- Create a lunchbox out of recycled plastic

Justification

Plastic pollution is a worldwide issue. Copious amounts of plastic are produced annually and most plastic ends up not recycled. This unrecycled plastic gets filtered into terrestrial and marine environments. Plastic pollutes the environment around us and inhibits the life of every species on Earth. Plastic never goes away. It is important to raise awareness and educate those around us about the ways we can start reducing plastic waste and recycling the plastic that already exists instead of creating more. We can start by learning how to recycle plastic in our own communities to create all sorts of products.

2. Literature Review

Fab Lab

In 2001, Massachusetts Institute of Technology (MIT) Professor Niel Gershenfeld founded MIT's Center for Bits and Atoms (CBA) where the first Fab Lab was created. His intentions were to blend the space between hardware, manufacturing, atoms, and software, information, and bits to create a collaborative manufacturing lab. A unique digital fabrication facility was created to help make all sorts of things. A Fab Lab can have a large range of machines, including electron microscopes, laser cutting machines, 3D printing machines, and many others. Professor Gershenfeld taught a course that was called "How to Make (almost) Anything." The course itself attracted a huge crowd more than what there group of researchers could handle, so they opened the second Fab Lab in the South End Technology Center. The Fab Lab community started to really expand and now Fab Lab can be found all over the world (Figure 1). The most important aspect of the Fab Lab is how individualized a project can be (Stacey, 2014).

Figure 1. Fab Lab worldwide network

Precious Plastic

Precious Plastic is an organization that was created in 2013 by Dave Hakkens (Figure 2). He started this project because he realized how much plastic is on the planet, how more plastic is made every year, and that less than 10% of plastic actually gets recycled. He began working on this as a graduation project for his design academy. He taught himself how to make small scale recycling machines and he shared them online open source. Hakkens won an award, he put the money towards hiring a machine builder so his machines could be improved and better for recycling on a small scale. Hakkens also did material research in countries all over the world, he wanted to ensure the machines could be built anywhere. This project is all about trying to boost plastic recycling worldwide (Figure 3). What Precious Plastic is doing is providing the global community with tools and knowledge to recycle on a small production scale. All techniques, designs, and tools are shared online for free (Hakkens, 2013).

Figure 2. Precious Plastic logo

Figure 3. A window display put on by Precious Plastic at Bjiernkorf in Amsterdam.

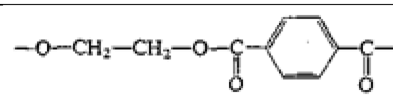
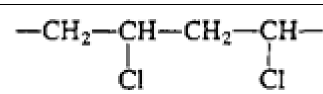
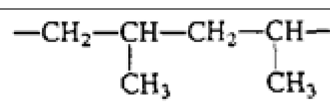
Polymers

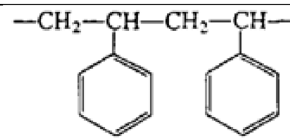
Synthetic organic polymers are what makes up plastic. Plastics can be molded when softened and when hardened they can retain any desired shape. “Plastics are polymers” (“Science of Plastics,” 2016). The word *poly* means many and *mer* or *monomer* means a single unit. Therefore, a polymer is made of many repeating units. There are different kinds of plastics, resulting in different kinds of polymers and structure (Table 1). Polymers have many characteristics and most polymers have some of the same general properties: resistant to chemicals, heat and electricity insulators, light in mass, have the ability to be quite strong, and they can be processed in many different ways to create fibers, sheets, foams, or intricate molded parts (“Science of Plastics,” 2016).

Different kinds of plastics and their properties

There are several kind of plastics, these plastics are divided into categories according to their structure and properties. Most of the time, the kind of plastic can be determined by the name or number that is printed on the product. There are 7 plastics that are most commonly found among daily users (Table 1) (Hakkens, 2013).

Table 1. Different Types of Plastic

Type	Commonly used acronym	Polymer and structure	Recycling symbol
Polyethylene Terephthalate	PET		1 PET
High-Density Polyethylene	HDPE	$—CH_2—CH_2—CH_2—CH_2—$	2 HDPE
Polyvinyl Chloride	PVC		03 PVC
Low-Density Polyethylene	LDPE	$—CH_2—CH_2—CH_2—CH_2—$	4 LDPE
Polypropylene	PP		05 PP

Polystyrene	PS		
All other plastics	OTHER	All other resins, layered multimaterials, some containers	

A helpful poster was created by Precious Plastic about the different melting temperatures of plastic. The poster lists all the different melting temperatures of PLA, PS, PP, PE, ABS, and PET (Figure 4) (Hakkens, 2013).

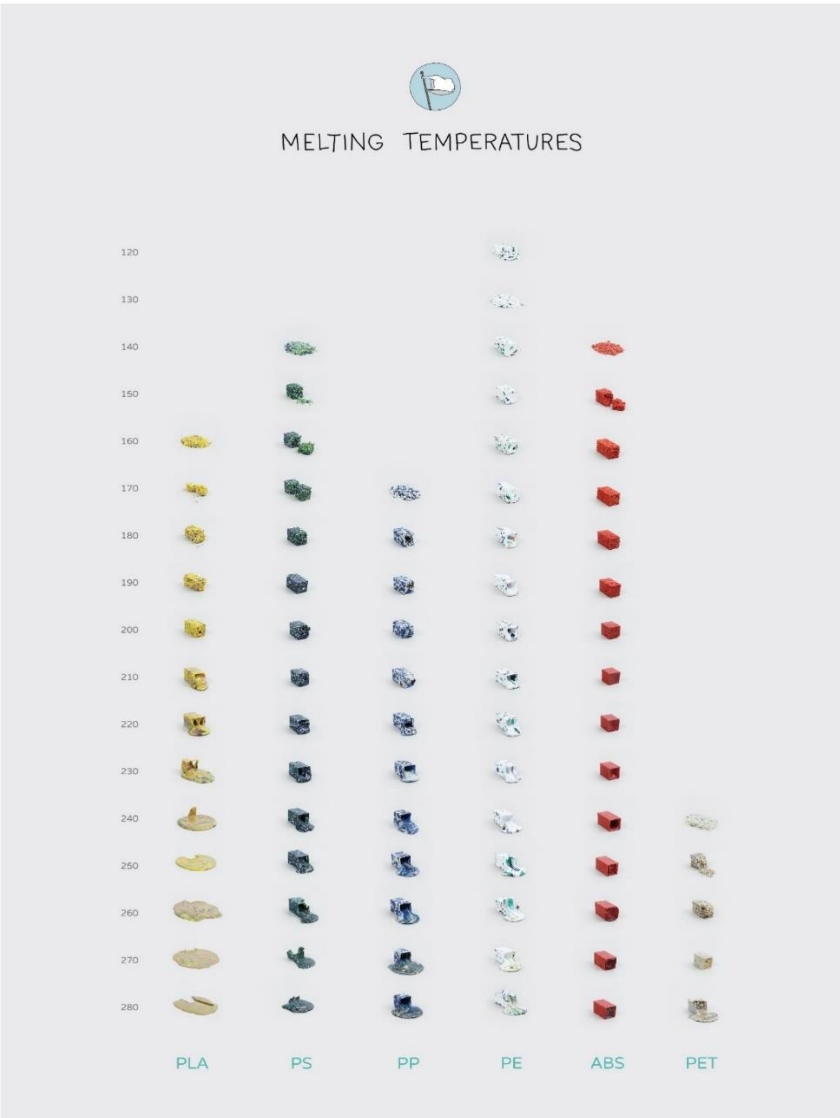


Figure 4. Melting temperatures of plastics

The Precious Plastic organization did some experimenting and testing on the most commonly found kinds of plastics. The visual properties, common uses, and the way each plastic burned are described (Table 2) (Hakkens, 2013).

Table 2 Visual Properties of Plastic

Type	**Properties**	**Common uses**	**Burning**
PET	clear, tough, solvent resistant, barrier to gas and moisture, softens at 80°C	soft drink, water bottles, salad domes, biscuit trays, food containers	yellow flame with little smoke
HDPE	hard to semi-flexible, resistant to chemicals and moisture, waxy surface, softens at 75°C	shopping bags, freezer bags, milk bottles, juice bottles, ice cream containers, shampoo bottles, crates	difficult to ignite, smells like a candle
PVC	strong, tough, can be clear and solvent, softens at 60°C	cosmetic containers, electrical conduit, plumbing pipes, blister packs, roof sheeting, garden hose	yellow flame, green spurts
LDPE	soft, flexible, waxy surface, scratches easily, softens at 70°C	cling wrap, garbage bags squeeze bottles, refuse bags, mulch film	difficult to ignite, smells like a candle
PP	hard but still flexible, waxy surface, translucent, withstands solvents, softens at 140°C	bottles, ice cream tubes, straws, flower pots, dishes, garden furniture, food containers	blue yellow tipped flame
PS	clear, glass opaque, semi tough, softens at 95°C	CD cases, plastic cutlery, imitation glass, foamed meat trays, brittle toys	dense smoke
Other	properties depend on the type of plastic	automotive, electronics, packaging	all other plastics

Another property of plastic is its durability, plastics degrade incredibly slowly in the natural environment. Plastics can last for hundreds of years before any sort of degradation can happen. Biodegradation is the breakdown of material with the help of microorganisms, plastics are quite resistant to this (Table 3). In the marine environment, plastics either float or sink and this is impart to the density. Plastics that often float are LDPE, HDPE, PP and other foamed plastics because they are lower in density. These plastics will receive more sunlight and wave action causing these plastics to fragment. The other plastics have a high density like PVC, PS, and PET; these sink. Plastics that sink remain intact for significantly longer periods of time because they are not exposed to direct sunlight. Once plastic gets broken up it can find its way into gyres and continue to fragment more. Degradation of plastics also depends on the type of plastic because the structure, the hydrophobicity, and the morphology are all different. Warmer ocean temperatures speed up the degradation process. As well as other environmental factors like light, pH, salinity, and many other factors can increase degradation (Doble, 2014).

Table 3. Degradability of various plastics

Material	Degradation rate (years)
Plastic bag	10-20
Commercial netting	30-40
Foamed plastic buoy	80
Plastic bottle	450
Monofilament fishing line	600

We can also look at how long these products are used before they end up recycled, in landfills or in the environment. Eight different industrial sectors and product categories were modeled to show the length of time a product is used before it is discarded (Figure 5). It shows that products generally have a shorter life span, especially products like packaging that are short lived (Geyer, Jambeck, & Law, 2017).

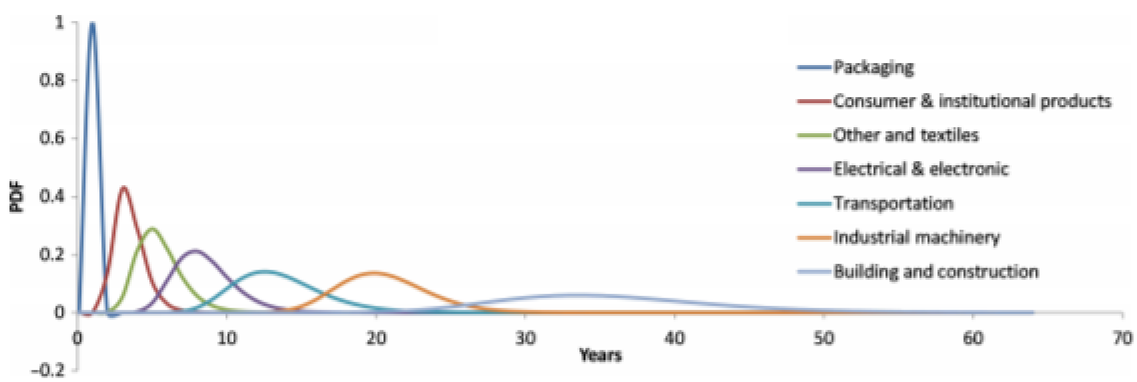


Figure 5. Product lifetime distributions

General Plastic Pollution

Plastics are consumed on a daily basis and are produced at astonishing rates. There are at least 250 million tons of plastic being produced annually. Plastics have become the material of choice because they are cheaply and easily fabricated (Doble, 2014). As of 2015, only 9% of plastic waste has actually been recycled. Most plastic has accumulated in landfills and the natural environment, this makes up the largest portion at 79%, and the other 12% gets incinerated (Geyer et al., 2017). The plastic that accumulates in the landfill, can cause serious environmental harm. There are long term risks, soil and groundwater contamination by the additives and breakdown of the plastic products. The chemicals in the plastic leach into the ground. Another issue with the usage of plastics, is that over 50% of plastics produced each year are single-use only products, for example packaging or plastic straws. Only about 20% of plastic is used for long-term infrastructure, like pipes or cable coatings. While the last 30% are plastics made for an intermediate lifespan, for products like electronic goods or vehicles. Since the invention of plastic, the production of plastics has drastically increased. The amount of plastic that is being produced annually is unstainable, the more plastic, the more environmental problems that will be inflicted (Hopewell, Dvorak, & Kosior, 2009).

Marine Pollution

In the ocean, plastic origins are 80% from the land entering the ocean through industrial discharge, littering of beaches, and runoff. The other 20% is produced from establishments at sea from sailors, commercial operations, maritime industries, and the military. Polymers are very persistent to degradation. Plastics that float degrade slowly via photocatalytic degradation (Table 4) (Doble, 2014) .

Table 4. Plastics often found in the Ocean

Plastic	**Specific gravity**
Gear-related plastics	
PE	0.92-0.97
PP	0.91
Nylon	1.14
Polyester	1.38
Packaging-related plastics	
PE and PP	0.92-0.97 and 0.91
PVC	1.38
Polyester	1.38
PS (Styrofoam)	<0.2

Plastic debris scatters the marine environment but plastic that is less than five millimeters in length are determined as microplastics (“What are microplastics?,” n.d.). These small plastic fragments are found everywhere in the marine environment, they are contaminants, and cause a great deal of harm to the surrounding biota. For example, in the North Sea, it has been documented that about 100 million kilograms of microplastics accumulate annually. Microplastics are formed in two main ways. First, plastic products can be manufactured in a microscopic size, these are mostly found in facial, hand-cleansers, and cosmetics. Second, large plastic materials from the sea and land can form microplastics as they breakdown. The longer plastic materials remain in the natural environment, they begin to fragment because they lose their structural integrity from physical, biological, and chemical processes. Plastics that sit on beaches are exposed to direct sunlight and high oxygen availability allow for the plastic to turn brittle and crack. Once these plastics make it into the water, waves and turbulence cause fragmentation creating microplastics. The process never ends because plastic never goes away. The fragments continue to get smaller over time and become nanoparticles(Doble, 2014).

Microplastics are commonly found to be ingested by marine species. These plastics are often mistaken for prey. Ingested material is found to be plastic bags, fragments of plastic, and plastic pellets. Starvation, malnutrition, and potentially death can occur as plastic blocks the digestive track or the stomach in species (Doble, 2014). A study was done on 95 Fulmars that had become beach washed in the Netherlands from 2002-2003. They were looking at the abundance of marine litter in the stomachs of these birds. In 2002, 98% of the 56 birds had plastics in their stomach with an average of 52 plastic particles. The following year in 2003, 39 birds were investigated and 95% had plastics found in their stomachs. On average 29 plastic particles were found in every bird. ("Marine litter monitoring by Northern Fulmars in the Netherlands 1982-2003," 2012). It is documented widely and data shows that plastic is found in Fulmar birds all across the world. In particular, the locations that are a greater distance from populated industrialized areas support that there is less plastic found in the stomachs of Fulmars (Figure 6) (van Franeker & Law, 2015).

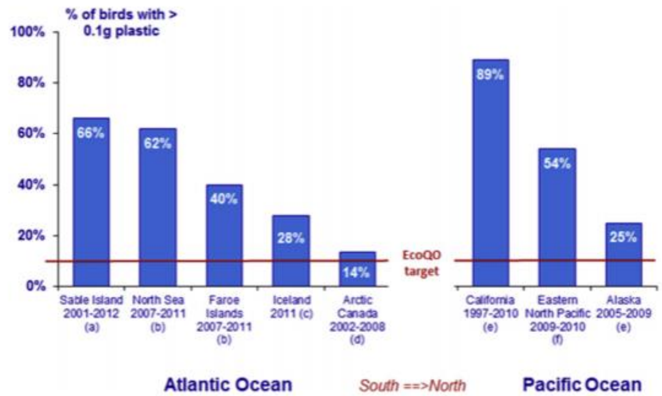


Figure 6. Latitudinal patterns in fulmars containing greater than 0.1g plastic

Another species often found dead due to ingestion of plastic, are sea turtles. Of turtles studied, 79.6% of them have been found to have ingested plastic. Plastic effects marine organisms in many ways, plastic can accumulate in the gut and create a sense of fullness causing the animal to starve to death and some may ingest sharp material that could potentially kill the organism. Turtles are not the only species effected by plastic ingestion. (Doble, 2014).

The Great Pacific Garbage Patch

A gyre is defined as “a naturally occurring vortex of wind and ocean current that rotates in a clockwise direction in the northern hemisphere and counter-clockwise in the southern hemisphere” (Doble, 2014). Essentially, a whirlpool effect is created and in the center of the gyre it moves very slowly and collects plastic debris. Five major gyres are found in the oceans of Earth in the North Atlantic, South Atlantic, Indian Ocean, North Pacific, and South Pacific. Every gyre contains plastic and persistent organic pollutants also known as POP.

The Great Pacific Garbage patch located in the North Pacific gyre, is estimated to hold 11 million tons of floating plastic (Figure 7). This patch of plastic covers almost 13 million square kilometers in the Pacific Ocean which is twice the size of Texas. The swirling vortex picks up plastic trash that was not recycled or that have been washed away by heavy rains and rivers. In the South Pacific gyre, few biota are seen living beneath. Not only plastic collects in gyres but hazardous chemicals too including gasoline, pesticides, manure, and sewage. The plastic particles that live in these gyres contain POP levels up to a million times higher than plastic found elsewhere in the oceans because they absorb the chemicals that swirl in the gyre. Gyres are often also referred to as toxic soup (Doble, 2014).

Figure 7. The approximate location and size of the Great Pacific Garbage Patch

Terrestrial Pollution

Plastic is littered almost everywhere across the globe in the terrestrial environment. As most plastics do not get recycled they end up in landfills, in the streets, freshwaters, along coastlines, and find their way into soils. About one third of plastic waste, is estimated to end up in soils or freshwaters. Soils have possibly become a sink for microplastics. Sewage has become a main distributor of microplastics. Sewage sludge is often used as fertilizers on fields, this means that several thousand tons of microplastics can end up in soils annually (“An underestimated threat,” 2018). Microplastics have been found in large rivers and lakes, they seem to be similar to those found in the marine environment. Although, a lot of uncertainty remains as the terrestrial environment lacks in-depth research investigating plastic pollution in the environment (Duis & Coors, 2016).

Harvey Mudd College

Harvey Mudd College (HMC) was founded in 1955 and is a private liberal arts college in Claremont, California. HMC is just one of the institutions that make up the Claremont Consortium. Harvey Mudd offers Bachelor of Science degrees in a wide range of majors. Deemed one of the best colleges because of their premier engineering, science, and mathematics programs in the United States (“About Harvey Mudd College,” n.d.). Currently, the school has 844 students with a gender ratio of 48:52, female to male. There is a low student to faculty ratio of 8:1 (“Fast Facts,” n.d.). HMC is a member of the U.S. Green Building Council.

Hixon Center

The Hixon Center for Sustainable Environmental Design at HMC began in 2015. It was created to help initiate, support, and coordinate activities and programs across the college that relate specifically to sustainability research, teaching, and practice. Their mission is to promote sustainability at the college through various research and active participation within the local community along with global level engagement.

The Hixon Center resides on three pillars, research, pedagogy, and campus sustainability. First, research, they work along the principle of learning by doing. They look to find solutions to man-made environmental problems. The research and initiatives start with local representations of sustainability challenges but are able to be scaled up to a global level. Specifically, the Hixon Center has been looking into ecosystem resilience, energy systems, mobility, water resource management, and climate change. The second pillar is pedagogy, HMC prides themselves on their rigorous studies of engineering, natural sciences, mathematics, and computer science but with a strong foundation in humanities and social sciences. They work to establish the next generation of leaders who can have the skillsets intellectually and outwardly to create an impact of their own work on society. Environmental science, natural resource management, and conservation opportunities coinciding with education and research are presented through the Hixon Center. The last pillar, is campus sustainability. The Hixon Center looks to use campus projects and initiatives to help promote environmental sustainability across the campus, and the consortium. They work to engage all members of the community including students, faculty, and staff throughout the Claremont Colleges, the City of Claremont, and further. They strive to create an open dialogue on topics like the environment and sustainability. Encouragement is also suggested for sustainable behavior for students both with their time on campus and with their time away. To help create sustainable change, the Hixon Center works to establish connections between the colleges and the surrounding community ("About the Hixon Center," n.d.).

The future of plastic consumption

Global plastic production and consumption is outrageous and has only continued to rise. From 2012 to 2013, a 4% increase was seen in the number of plastics produced (Le Guern, 2018). By 2050, there will be more plastic in the ocean than fish. Over 60% of plastic that ends up in the ocean comes from only 5 countries: China, Indonesia, Philippines, Thailand, and Vietnam. Plastic consumption in Asia by 2025, is predicted to increase by 80% and surpass 200 million tons ("Plastic Oceans," n.d.). In 2014, 311 million metric tons of plastic was produced. By 2050, the amount of plastic produced is predicted to reach over 1,124 million metric tons. Over 20% of global oil consumption will be used to make plastics in 2050 instead of the 6% that was used in 2014. And plastics will go from producing 1% of the carbon budget to 15% by 2050 ("Rethinking the future of plastics," n.d.).

3. Methods

The majority of the 5 week research was conducted in the FabLab in Ísafjörður. I, the researcher worked on the project for over 30 hours each week. During the first week of the project, I first meet with my advisor, Þórarinn and Precious Plastic organization member B. Steinar. I proposed my initial idea of reusing plastic to create a lunch box and I liked the idea of integrating education. There was a significant amount of pushback in making a food related object. I continued to push my idea because a lunch box has a purpose and will not be another piece of junk that will get thrown away quickly.

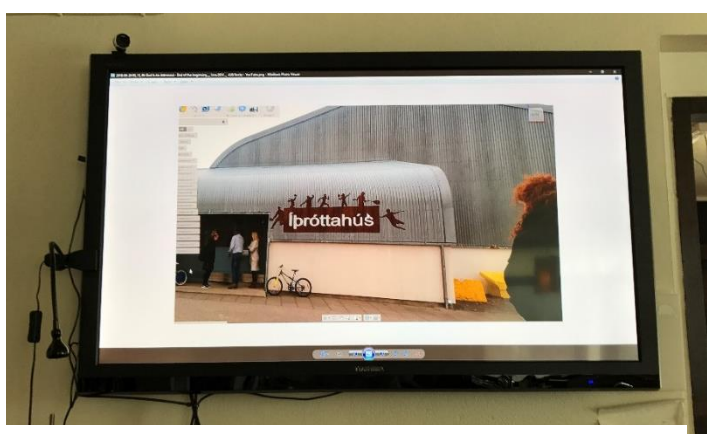


Figure 8. Proposed sign design and location

We went to the elementary school in Súðavík, Iceland where we met with some teachers. Þórarinn had prepared a plan to create a sign for the gymnasium at the school. We went to measure out what the size of the sign should be and where is should be located. After we figured out the location, Þórarinn suggested to the team of teachers, the possibility to have the students create the letters of the sign out of reusable plastic. The raw material will be blocks of reusable plastic and students will use the milling machine to cut out the desired letter. Students can pick out the color and a workshop could potentially be run to teach them how to use the plastic shredder as well as educating the students on plastic pollution. The students of the school came to the FabLab where we talked to them about Precious Plastic and introduced the idea of reusing plastics to create the letters.

Þórarinn took us to Þingeyri, to the Blu Bank. It was a space made for the creation of ideas. B. Steinar and I got to talking and he finally agreed to the lunch box idea. The pushback originally was impart to the food safety aspect but what matters is the importance behind the concept. This day we started to design the project. The original idea was a rectangular lunch box that could fit two snacks and a sandwich. I sketched out the first design (Figure 9).

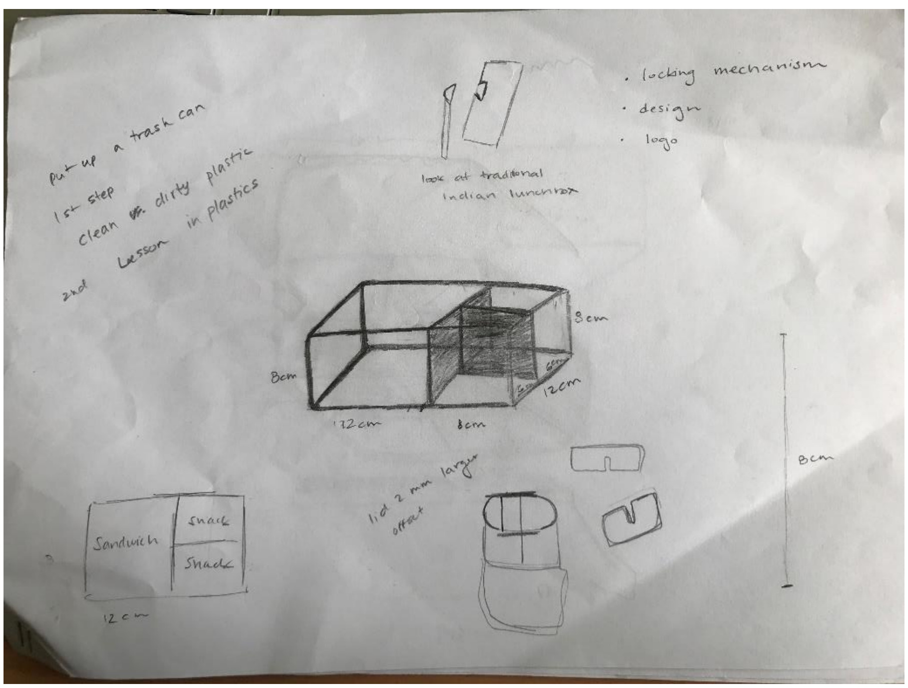


Figure 9. First sketch of lunch box

B. Steinar suggested to look at traditional Indian lunchboxes. A new design was sketched, it is like a traditional Indian lunchbox but more square in order to fit a sandwich. A loaf of bread

Figure 10. Measuring a slice of bread

was measured with a measuring tape to help determine the dimensions of the box (Figure 10). Dimensions of 13 cm by 13 cm was determined, this allows for sandwich to fit inside. The new sketch shows how the lunch box would stack and the use of dividers (Figure 11).

There was discussion about the locking mechanism of the lunch box. It was concluded that there will be a strap made out of plastic and clip to hold the strap tight on the lunchbox. Using the clip of a backpack strap, the clip was measured using a digital caliper measuring tool and 2D model was made. Dimensions were sketched out on to paper. B. Steinar created 3D models of all of the sketches on a software called Rhino. The base plastic box and corresponding lid were 3D printed using Ultimaker^3 and Ultimaker^2 machines. After seeing the prototypes for the first time, modifications were needed. The box needed to be slightly conical in order for the mold to work, the lid needed to be tighter, and a marking in the lid to help fasten strap should be implemented.

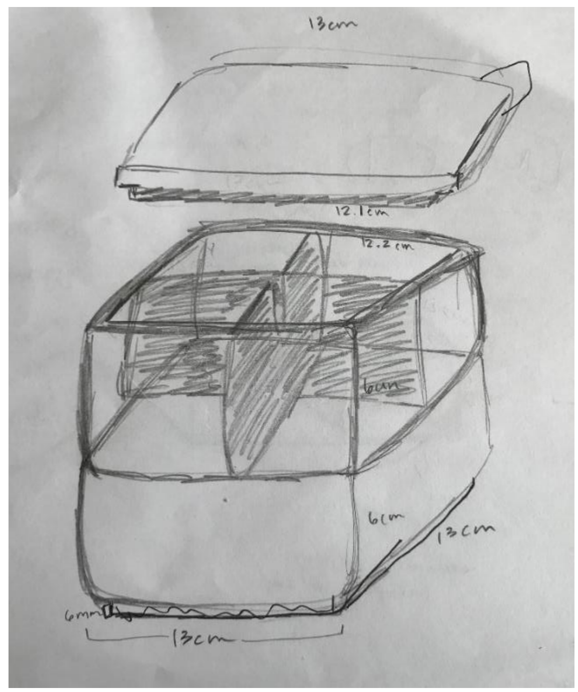


Figure 11. Second sketch, inspired by the traditional Indian lunchbox

An interview was setup with B. Steinar at the FabLab. The interview was completed Friday, April 27th, 2018. The purpose of the interview was to get insight into the interviewees experience working with plastic, education, and understand why he choose to be a part of the Precious Plastic organization. I prepared questions for a semi-structured open ended interview (Table 4).

Table 4. Prepared interview questions for B. Steinar

Questions
• You are a product designer… how did you first get started and why did you choose to become a product designer? • Why and how did you get started in the precious plastic organization? • How did the precious plastics organization begin? • What are your and/or the organizations goals in regards to reusing plastics? • What do you think is next for precious plastics?

- What is your favorite thing to create or have created with reused plastic?
- What is the worst/your least favorite kind of plastic?
- What is your favorite plastic to work with?
- What is the worst/your least favorite kind of plastic?
- What machine do you like to use the best to create reusable products? Why?
- Have you found anything interesting you can do with the machines or the products to make them different and interesting?
- What has been your favorite part about working with the precious plastic organization? Why?
- What were you experiences like in Beijing? And anywhere else you went? Was it impactful? Why?
- Why did you come back to live in Iceland?
- What is next for you in the precious plastic organization? Any new workshops?
- I hear you do some other cool stuff in regards to sustainability, waste management, and the environment… what are those?

At the end of the first week, there was a change in plans for the development of the lunchbox. The mold we were intending to create would not work because of the materials that are available for use in the FabLab here. The original plan was to make a mold for the base, lid, and clip (Figure 12).

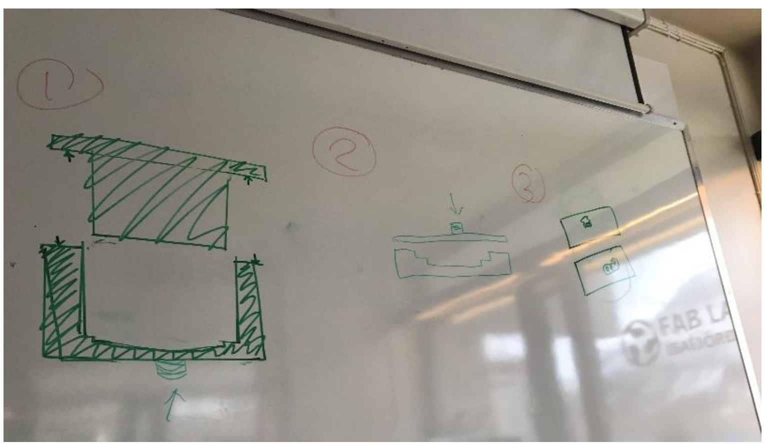


Figure 12. The original plan for 3 molds

The new plan imposed was to create one large cube mold. I would learn how to weld and create the mold out of metal pieces. The mold no longer needed to be conical because there would be a removable side allowing for the cube to be removed easily. Plastic cubes were to be made and would get cut into the desired shape.

The new plan:

1. Assemble shredder
2. Collect Plastic
3. Separate plastic
4. Shred plastic
5. Find metal for box mold

6. cut the metal to dimensions of 15cm X 15cm
7. Weld into the box shape
8. Melt plastic in box
9. Put plastic in milling machine and cut according to drawings

The following week, I downloaded the software Fusion 360. Fusion 360 is a free 3D CAD/CAM/CAE design software for product development. Fusion 360 helps make solid modeling precise and can make a design easily manufacturable ("Learning | What is Fusion 360," n.d.). I followed the program "Learn Fusion 360 in 60 Minutes" to learn the basics of the modeling program. I also watched other videos and tutorials in order to better learn the software.

Fusion 360 was used to model every part of the lunch box. There are 5 pieces in total that were created. These pieces included the base box, the lid, the clip, and two dividers. All five pieces were first sketched in the program (Figure 13-17). To get the 3D model, the pieces had to be extruded to get the desired height.

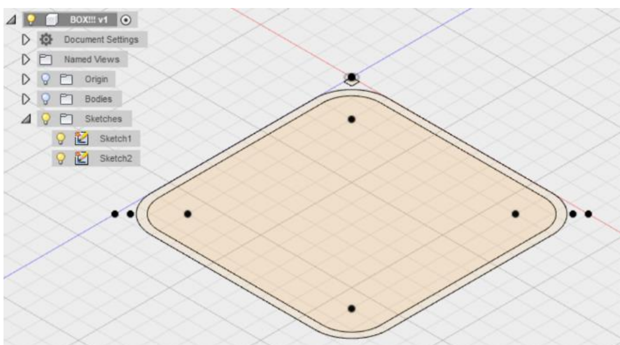


Figure 13. Sketch of the base box

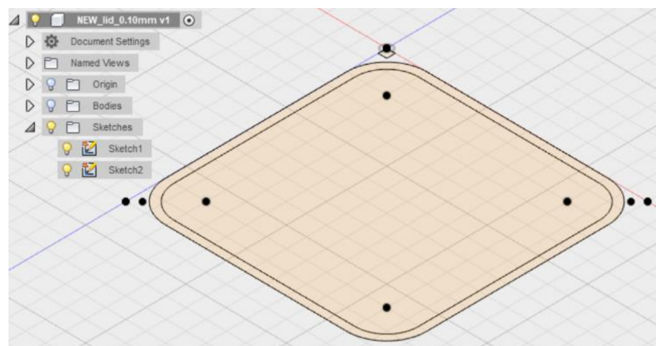


Figure 14. Sketch of the lid

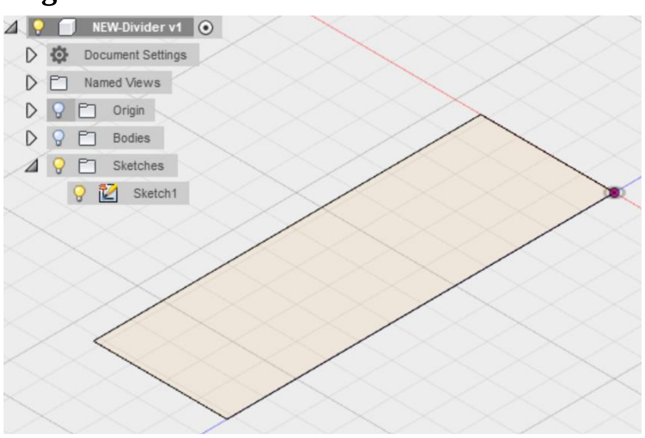


Figure 15. Sketch of the first divider

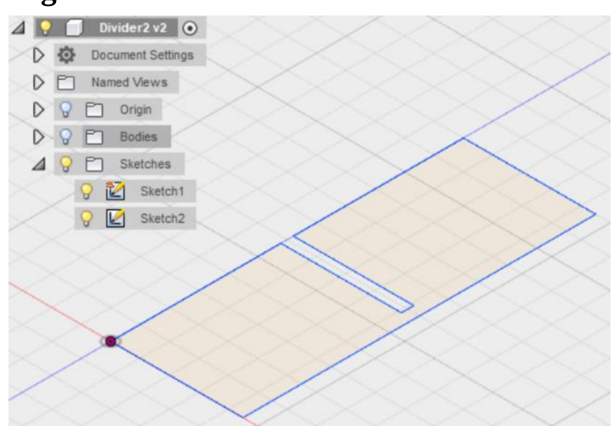


Figure 16. Sketch of the second divider

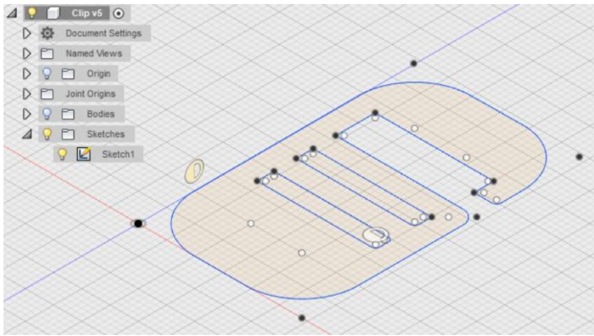


Figure 17. Sketch of the clip

For example to model the first divider in Fusion 360, the process was easy because it is a rectangle. First, the create sketch button was clicked and a plane was selected where the model was to be made on the screen. Next, the rectangle option was selected and another tab appeared where 2-Point Rectangle was selected. From there the modeling plane was clicked and it can either be pulled to create the rectangle to the desired length or fill in the desired dimensions in the given boxes. In this case, I typed in 42mm and 121.75mm to form the divider sketch. Now the sketch has been completed. Next is to extrude the sketch to make it a 3D model. The create button was clicked and tabs were displayed, and extrude was clicked. The extrude button gives a box to enter the desired distance to extrude, where I entered 4mm. The divider is the easiest piece to make, it gets more complex when designing the base box, lid, and the clip. Other functions of hole and fillet are used. Along, with more complex dimensions and angles, as well as more of them.

Each modeled product was 3D printed. To 3D print, the file icon in the top left corner of the screen was selected, and the following tab of 3D print was selected. A screen appeared with information regarding the 3D print, the only button selected was OK. The file was saved as a .stl to the desktop. Another program called Ultimaker Cura 3.3.1 was downloaded. The Cura application was launched. The kind of printer being used was selected, in this case I used an Ultimaker[2]. The desired model was opened, I clicked File, Open file(s), and then selected the file I wanted to 3D print and hit enter. The modeled piece appeared on the screen. In order to print properly, the product needed to be rotated to lay flat on the machines base. To complete this action, the piece was clicked on and then, the rotate button was selected. Three different colored circles appeared on the screen. The red circle was clicked and pulled down by the mouse until the angle read 90 degrees and the mouse was released. A USB drive or SD card was inserted in the computer. The button prepare in the bottom right hand corner of the screen was selected. The time it takes to print the object appeared and a new button called Save to File appeared. This new button was clicked and the file was saved as a .gcode. This document then got moved onto either the USB drive or the SD card. The disk drive was then removed from the computer and was taken to the 3D printer and inserted. Then I turned on the 3D printer by flipping the button on the back of the computer to on. Print is selected on the front the machine using the wheel, and using the wheel I scrolled through all the various products to print until I found my piece I wanted to print. I pressed the wheel and selected yes. A few hours later, or 20 hours later the product was done being printed.

After 3D printing all the pieces. Modifications were made. The dividers were too tall and hit the top of the lid barely, they needed to be reduced in size. The lid did not fit tight enough to the box. The inside of the lid dimensions were now to be only 0.1mm different than that of the box, so it would allow for a nice snug fit. And the bottom of the box, the dimension was reduced allowing for the snug fit when stacking the boxes together. The designs were modified in Fusion 360 and reprinted. I also made a strap for the box. I cut three strips out of a plastic grocery bag around 4cm in width and 100cm in length. I tied the three pieces together and proceeded to tightly braid all the way down until I ran out of material and tied a knot at the end.

Another, interview, briefly was held on May 9th, 2018. I did a phone interview with one of my old research professors, Z. Dodds. In summer of 2016, I worked with him and a group of students creating computer science curriculum for middle school students. We spent a portion of the summer traveling and holding professional developments with educators. He is a computer science professor at Harvey Mudd College and has a strong interest in education. The purpose of the interview was to get his perspective and thoughts on if incorporating Precious Plastic on a college campus would be feasible. The interview was only a few minutes because it was a spur of the moment phone call, it was a very informal open-ended phone interview. I explained to him the project more in-depth than our email conversation, and my main question for the interview was “Do you think it is possible to integrate it?” He asked me several questions about what I am doing, my major, and other logistical questions. And the most important question he asked me during the interview was “What additional steps do you imagine being part in bringing the project to the 5Cs?”

The plastic cube mold was first sketched on paper. The mold sketch was made to have a removable bottom. It was then changed to become a mold made with two u-beams welded to a base plate and two plates that are screwed together to the beams. It makes it easier to knock the plastic cube out of the mold. The mold was modeled in Fusion 360. From this model a blueprint was made. The blueprint had the various dimensions, all the different plates, and the whole mold (Figure 18). This blueprint was given to metal workshop, where the pieces were prepared. Once the pieces were ready, they were picked up and brought back to the FabLab.

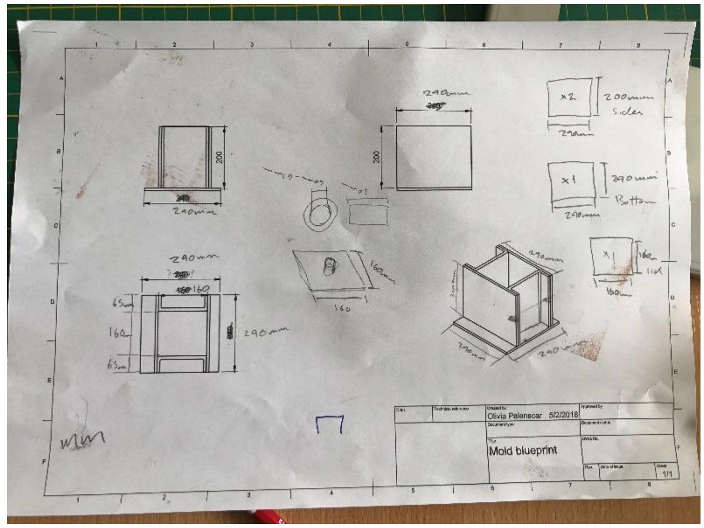


Figure 18. Blueprint for metal mold

From there I went onto to angle grind the pieces of metal because they were not stainless steel and had a coating on top that needed to be removed in order to allow for a better weld. To angle grind the metal pieces, I used an angle grinder and a wire brush attachment (Figure 19). I wore a lab jacket, safety gloves, and protective eye wear. To make sure the metal piece I was working with did not move, I secured the piece to the welding table using a table clamp. I took the angle grinder and grinded down the plate from a red color to a nice grey/silver color (Figure 20). All the pieces were grinded down on every side.

Figure 19. The metal plate before being angle grinded

Figure 20. The metal plate after being angle grinded

After all the pieces were grinded, and positioned to the desired mold shape, held together by TOPEX F-clamps. One hole was then drilled through the u-beam and metal piece on each corner of the mold. The plates were screwed together to the u-beam to insure a tight fit (Figure 21). This will make it easier when the plastic is melted because the u-beams can be removed and the plastic cube can be removed from mold easily.

Figure 21. The mold before being welded

The mold was transported to the metal workshop. I practiced welding on some scrap metal to get the feel for what welding is like. I made sure that I wore a welding helmet, a lab jacket, and protective gloves. Before welding the mold together, I first connected the work clamp to metal table, this ensured that electricity would flow when I was welding. The machine was turned on and settings were adjusted for speed and amount of gas that was exerted. I then took the welding gun and pressed down on the button and held it close to the u-beam and the metal plate. I slowly moved the welding gun along the seam of u-beam and base plate (Figure 22). I stopped and looked at it several times and if the wire coming out of the welding gun was too long, it was trimmed using metal cutters. The two u-beam pieces of the box were mig-welded to the base structure (Figure 23).

Figure 22. Welding

Figure 23. The completed weld

Another interview was set up with Ó. Jóhannsdóttir, a school teacher. This was completed on Monday, May 14th, 2018 at the elementary school in Ísafjörður at 8:00pm. The purpose of the interview was to get insight on a teacher’s perspective about bringing environmental education and plastic recycling into a school setting. I prepared questions for a semi-structured open ended interview.

Table 2. Questions Prepared

Questions
• Where do you teach? • What grade level do you teach and what classes? • Why did you become a teacher? • Why do you like teaching in the fablab? • What has been the best part about teaching class in the fab lab? • Do your students like working in the fab lab? • What do you think about integrating environmental education into the students class in the fablab? Do you think students would respond well to it? Why or why not? • What do you think students level of understanding of why we should reuse plastic? • If students could making anything they wanted out of reusing plastic, do you think they would like to do it? • How do you think integrating this project of reusing plastics on a college campus would be beneficial? • What age level do you think would be the most reciprocal to reusing plastics? • How do you think the best way to introduce and teach this to students? Workshops? etc…

Next, the plastic shredder was assembled. The metal framework was welded together a year ago by exchange students and was to be used for something else but now it is for the shredder. Other metal pieces needed to be welded to the framework that could bolt on the shredder and the motor. The motor was found dumpster diving. It used to be a fishing net motor. The pieces were brought to 3x Tecniology where someone helped out and welded it together for us (Figure 24). All the pieces were brought back to the workshop where the shredder was then officially assembled. The shredder was secured to a large metal framework with bolts. The motor was also secured to framework with bolts and was attached to the shredder. The hopper came in two pieces, it was bolted together and then bolted to the shredder. Finally, the shredder had been built and now had the capability to shred plastic (Figure 26).

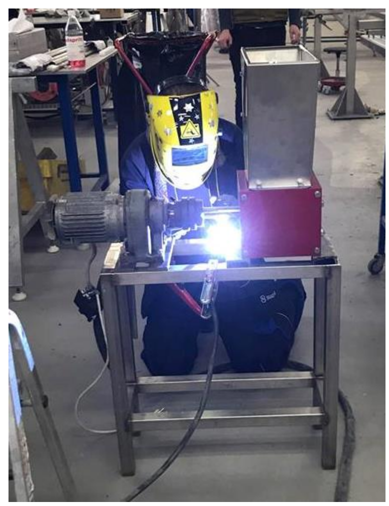


Figure 24. The frame being welded

Plastic was collected for several weeks in my house and I went dumpster diving at the high school to collect more plastic. After collecting all the plastic, it was washed and dried. The plastic shredder prefers to work with cleaned plastic. Once I had enough plastic, I separated the plastics out according to their recycling symbol. I also collected 6 large painters' buckets, that I labelled each with a different type of plastic. I choose to start shredding the PP plastics first. I made sure I did not mix my plastics because then the product will be 100% pure and can easily be shredded and melted again. The bucket labelled PP was placed beneath the shredder. The motor was turned on with a switch and the shredder started to spin, I tossed plastic into the hopper and used the Poke Master 3000 (Figure 25) to help the large pieces of plastics get shredded. As the plastic was shredded it fell out the bottom of the shredder and into the bin where it collected. The shredder was cleaned with an air compressor that blew all the pieces of the first kind of plastic out before a new kind of plastic was placed in the shredder. I continued to shred plastic until I felt I had a large enough supply to make raw material with.

Figure 25. Poke Master 3000

Figure 26. The shredder

To create the raw material, the plastic cube, a small amount of shredded plastic was added to the bottom of the mold. The mold was placed into an industrial oven where it was melted (Figure 27). I continued to add plastic in layers and let it melt each time before adding more plastic otherwise there could be unmelted plastic in the middle of the cube. You could tell the plastic was melting because it looked shriveled up and glossy (Figure 28). After enough plastic had been melted, the mold was wheeled to the metal workshop and then

Figure 27. Industrial oven

Figure 28. Photo series of melting plastic

compressed. The lever was pulled down and a plate on top of the plastic pressed down (Figure 29). This compressed the plastic into a solid block. After the mold cooled, the screws were removed on the sides of the mold. The u-beams were removed and the plastic block was knocked out of the mold (Figure 30).

Figure 29. Compressing the mold

Figure 30. Unmolding the plastic

I purchased 6 milling bits. These were high quality cnc bits single flute longer spiral router carbide end mill cutter tool, 6mm x 62mm OVL 90mm. One milling bit was secured into the milling machine. The plastic cube was placed inside the milling machine. One of the 3D models that I had created earlier was then selected and the milling machine cut the plastic cube to the desired shape. The plastic piece was then sanded down removing any rough edges.

After all the pieces were cut out of the milling machine, the lunch box was assembled. The lunch box consisted of the base, the lid, and the two dividers that were placed inside. The plastic string was tied around the lunch box and secured with a bow to keep the lunch box well held together.

4. Ethics

I worked with several interview participants, they were given a waiver that included the outline of my research project and what I wanted to use the interview for. The waiver explained that this is completely voluntary and they had the ability to conclude the interview at any point. The waiver was also to receive permission to record the interview and quote the interviewee. The interviewees were also asked permission to use an abbreviation of their name and that would be referred to in the paper for the purpose of some confidentiality. All three interviewees were over the age 18 and each signed the waiver.

5. Results

The pieces of the lunchbox were modeled in Fusion 360 and the final versions are represented in the following Figures (Fig. 31-34). The clip was modeled with intention of being able to help secure the lunch box using a strap. After, putting the lunch box together, the clip did not benefit the lunch box and has been eliminated from the final product. Although the clip was still modeled (Figure 35) and 3D printed.

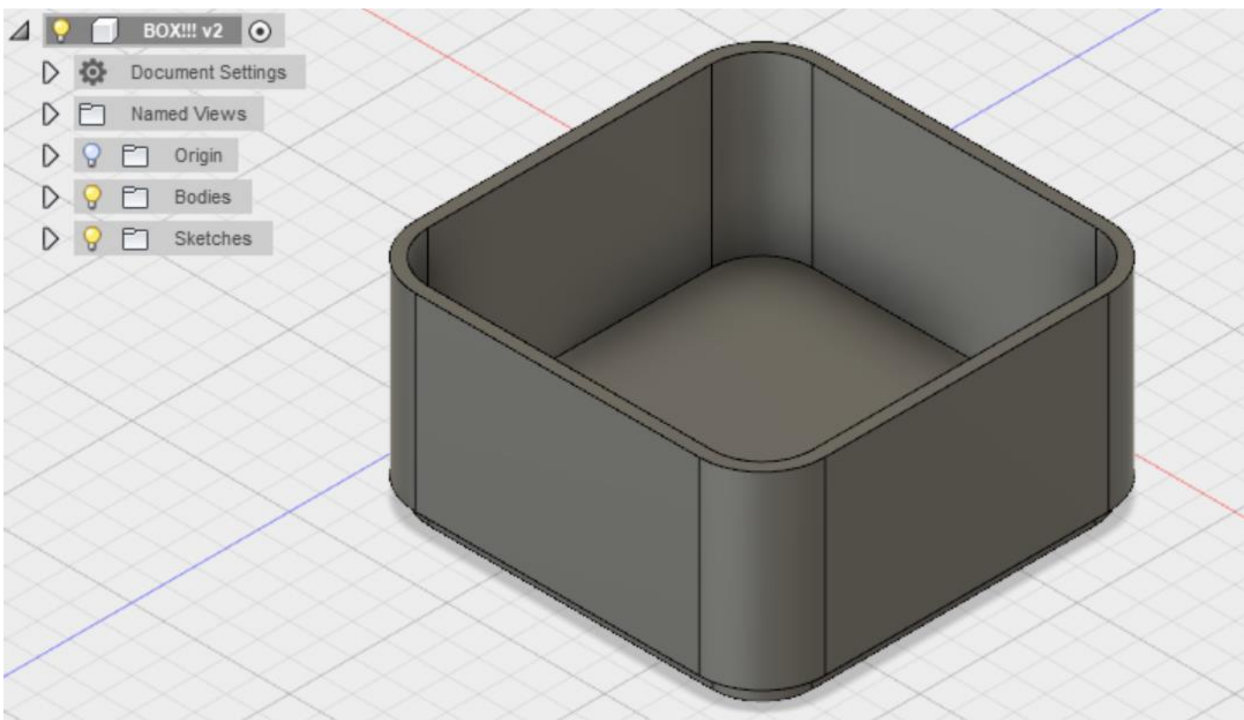


Figure 31. The modeled base container

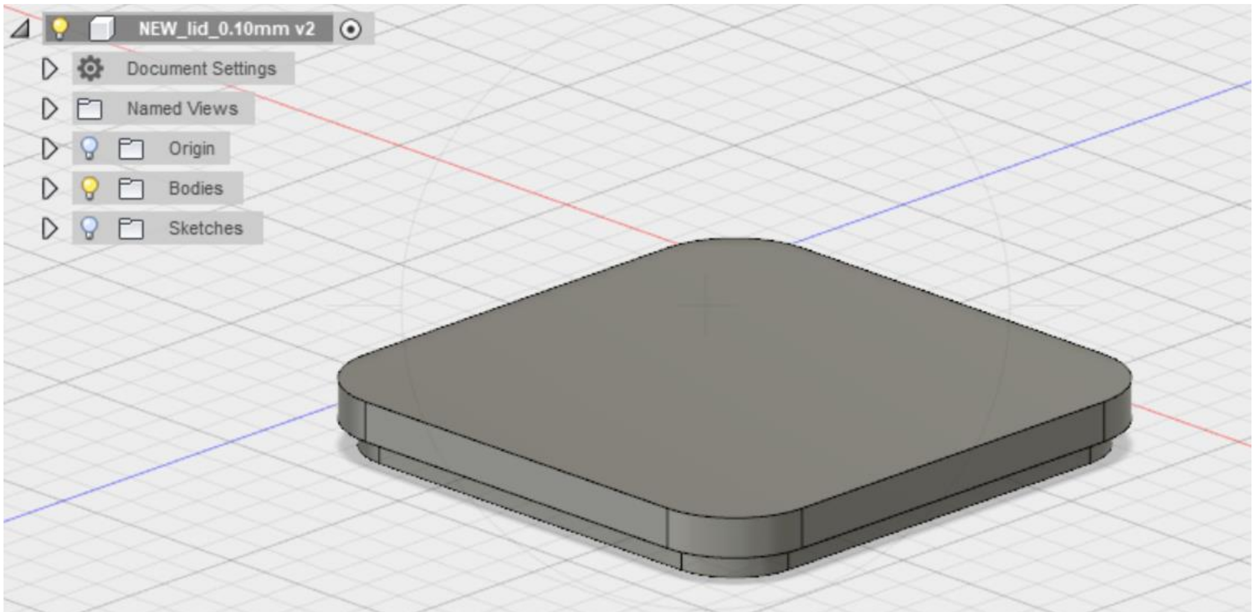


Figure 32. The modeled lid

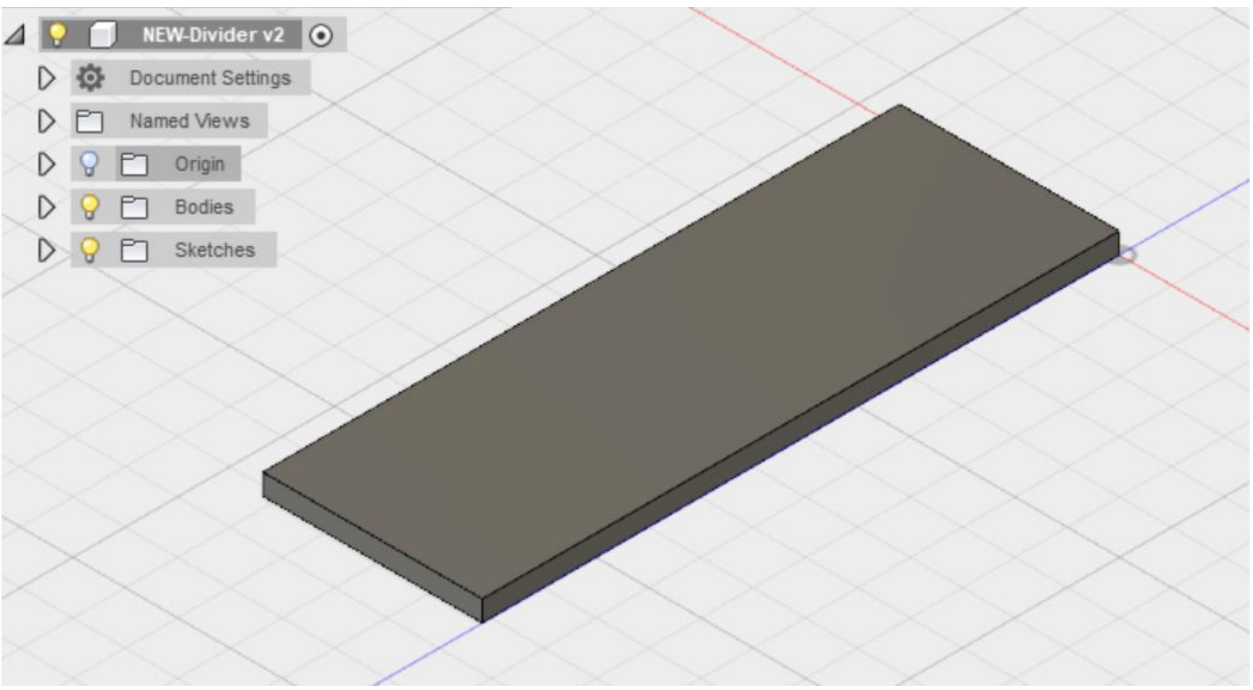


Figure 33. The modeled first divider

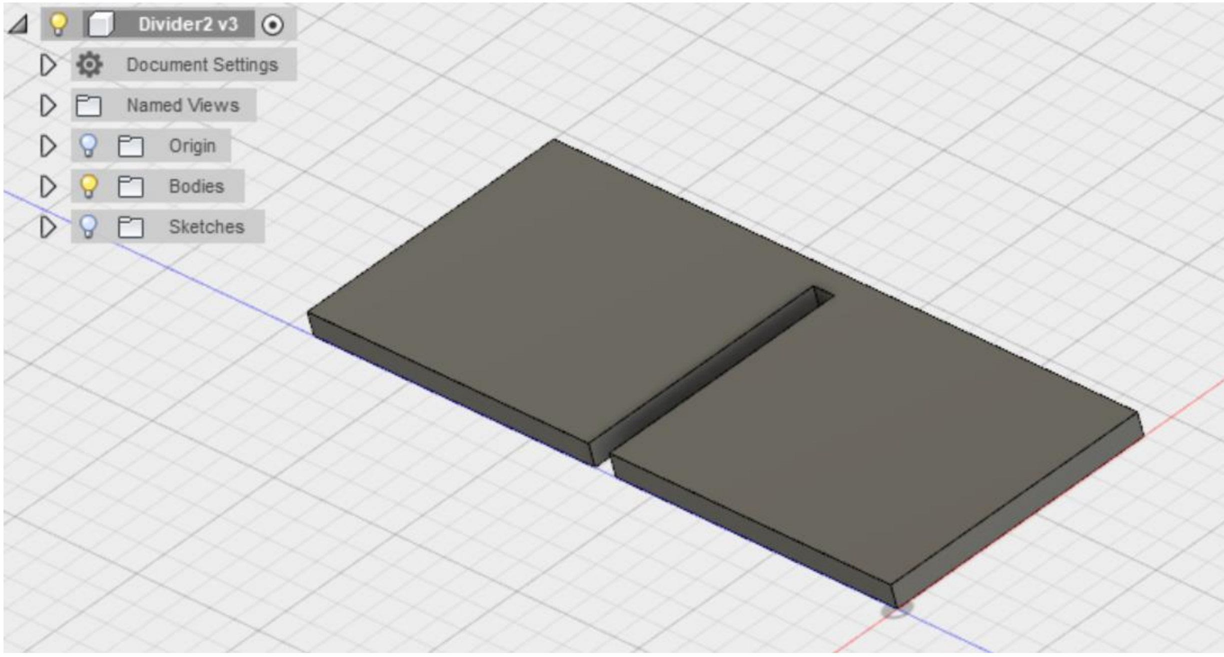


Figure 34. The modeled second divider

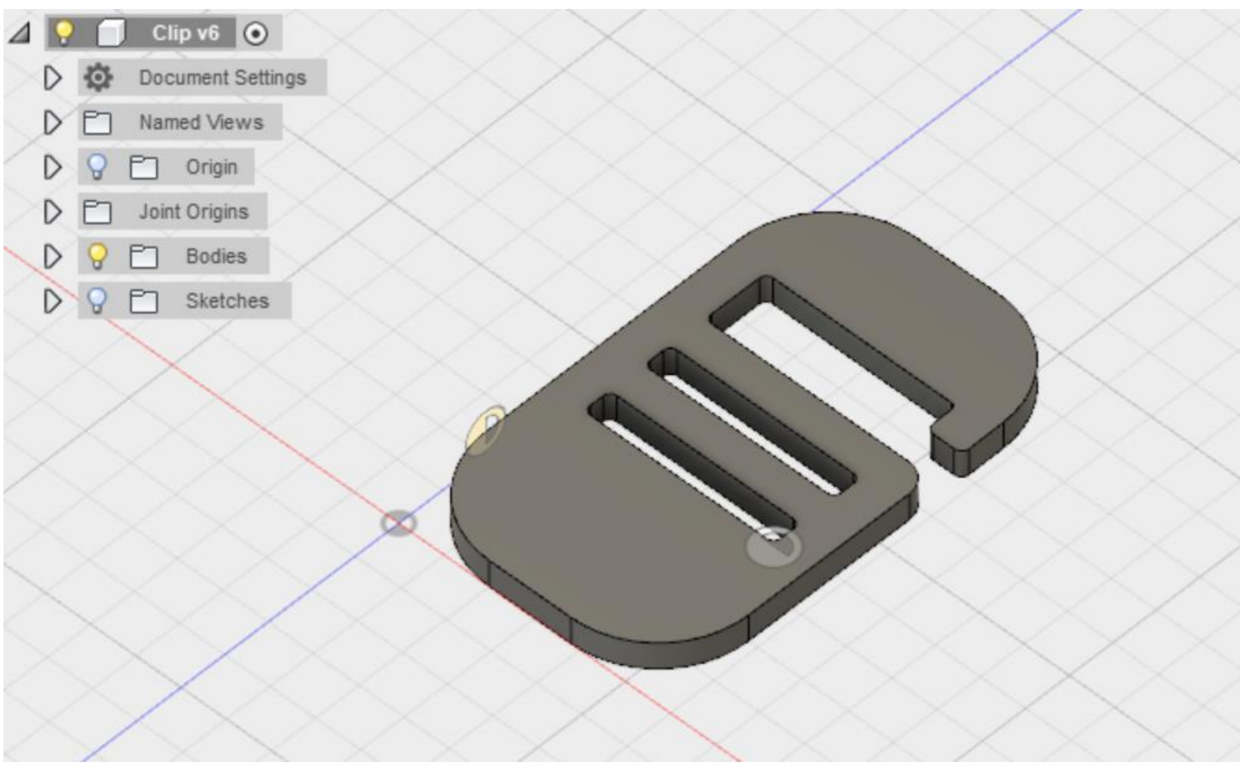


Figure 35. The modeled clip

Prototypes of the lunchbox pieces were made using the 3D printers. The lunchbox base, lid, dividers, and the clip were all 3D printed (Figure 36-38).

Figure 36. 3D printed lunchbox

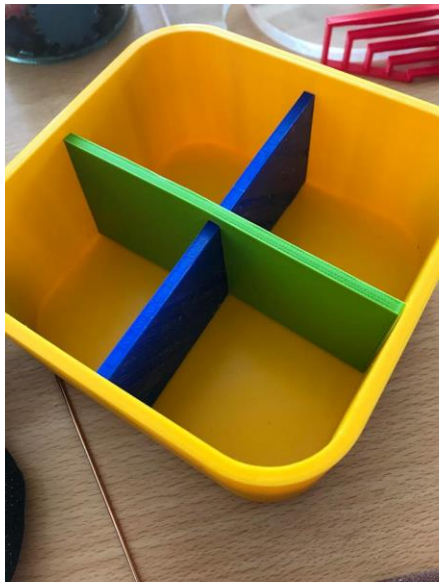


Figure 37. Interior with dividers

Figure 38. Clip

Due to short duration of the project, only two raw material slabs were produced from recycled PP. The lid is made out of 100% recycled plastic (Figure 39). The strap was also not included in the final product because the lid fits snuggly.

Figure 39. Completed lunchbox

6. Discussion

Building a lunchbox, was more about the concept behind it than anything else. Some may not understand why I wanted to make a lunch box. I made the lunchbox because I wanted it to have a purpose. I did not want to make another piece of junk that would become obsolete in someone's life after a short period of time as most plastic products do. A lunchbox made out of reusable plastic is to be purposeful, plastic bag consumption is off the charts and only continues to rise. This product will not be mass produced anytime soon but it can help people understand that we can recycle plastic on our own to make products that are useful. It shows that you do not need to go buy plastic bags or Tupperware you could make it yourself with the plastic waste from your very own household.

I really thought the process of recycling on a small scale would be quick to set up. It took a lot of time to actually get this project off the ground. There were always issues. The shredder did not fit the motor at first, so we had to get another piece delivered. There were many places the shredder needed to be welded to the metal frame, that as amateurs we could not do because it needed to be secure and properly done. We needed metal pieces to make the mold and they kept being placed on the back burner but eventually got done. There was just a lot of waiting, since I was not an expertise in any of this project, it relied heavily on the help of others. I was always a part of it but it was a whole new learning process for me. This was a new field for me that I have never stepped in before and I learned many new skills including computer 3D modeling, angle grinding, and welding. This project also identifies that someone who knows nothing about plastic recycling can do it. I did not know how to do most of the things before this project began to make this product. The point has been proven that anyone can put together a successful plastic recycling workshop because I was able to produce raw material made from plastic. There was a lot of experimentation. I tried to melt PET plastic to form a cube but was quite unsuccessful. It did not work as well as PP because it has a burning temperature closer to its melting point and we were using an unfamiliar oven that was built to reach higher temperatures. A majority of the creation of the final product did not happen until the last two days of the project period.

I have learned so much during the process of creating my own recycled product. Plastic is often not labelled well, this makes it hard to determine what kind of plastic it is. The lids to containers usually go unlabeled. And often times, plastic has stickers on them and those are really hard to get off without leaving any sticky residue behind. This project has really opened my eyes to plastic waste. I try to avoid using as much plastic as I can but I still cannot get away without using any of it. Being in Iceland, plastic is everywhere. By everywhere I mean a majority of foods are wrapped in plastic or in plastic containers since most products are imported. This is a good place to set up a recycling workshop because plastic is so widely used among products. Also, Icelanders are way better at recycling than I have ever seen before. I know it is just what people have grown up with here but it is not like this in the United States. All recyclables go into the same bin unlike here in Iceland where plastic, paper, glass, and metal are all separated out. I find that to be much more of efficient and smarter way to recycle.

I am passionate about education and I think that this could be reciprocated at any age level. It would have to be tweaked for younger ages as they would not understand the concept behind the lunchbox but if they could make something that benefits them like a toy or game I believe they could be interested in recycling plastic. It would be a little more difficult for secondary school age students because they may deem it as “not cool” or “lame” so that would need some tinkering with. If something was put in front of them that was really cool and it was put forward that they can create a very individualized project it could work. Although here in Ísafjörður, one the schools main principles is sustainability and that could help promote this plastic recycling work shop very much. I learned this through my interview with Ó. Jóhannsdóttir, she also told me that if students bring plastic to school they must take it home with them. It is inspiring to see that sustainability is taken seriously at the schools here. It would be great if this project could influence student’s thoughts about the environment and climate change, and how we can make a difference in our world through something like this project. Also, when we went to the school in Súðavík, the idea of using recycled plastic as the material of the letters was strongly reciprocated. The teachers really loved the idea and seemed to be genuinely interested in using recycled plastic as the raw material. The students came to work in the FabLab the last week of the project and we brought them over to tell them about the process and how they would hopefully be implementing this into their sign. The kids instantly seemed intrigued and excited to learn how they could do this. Although, I still strongly believe that college students are the best age that this could be brought to, and it would make the biggest impact.

Harvey Mudd College and the rest of the Claremont Colleges I feel would be able to integrate this into their campuses. Currently HMC, has a waste diversion initiative that started over a year ago. There is compost, recycling, and trash bins. They are really trying to reduce waste especially food waste. And if we can add reducing plastic waste, it would help build on this initiative even further. I spoke to one of my old professors, Z. Dodds, and he really feels that this is an incredible idea and he has been teaching for a very long time. He believes that this can "100% be integrated." Engineers could easily build the machines and learn how they work. It is exciting for anyone to make something like this and I am sure they could make major improvements to make them even better or create something even cooler. The engineers would be able to create molds and help to get this off the ground. It might even get started this summer, as Dodds said he would bring the idea to the summer research students. Students at the college could be inspired to use less plastic and see what they can make with it. Being a college student myself, I have noticed the copious amounts of plastic that accumulate on a college campus. For instance, red solo cups are everywhere. How cool would it be if those got turned into reusable cups instead of throwing them away after one night of parties and buying more? Laundry detergent containers, plastic disposable coffee cups, food containers, plastic bags, shampoo and conditioners bottles, the list goes on and on but there are countless amounts of plastic that could be recycled on this campus in a purposeful way. On campus we could set up workshops for the college students and even the surrounding community of Claremont. It would be incredible to introduce small scale recycling to this town. We have all the tools to create something big for this town, there are the right people, the right attitude, and the right kind of administration to actually make this happen.

I believe, if this is brought to an overall smaller community like the town of Ísafjörður or a smaller college like HMC and/or the Claremont Colleges in general, it could really be beneficial. If all the proper machines: shredder, extruder, compression, injection, were allocated to these smaller locations and a workshop was created, it could become incredibly beneficial for the community. All plastic recyclables could be sent to this workshop to be turned into something new and improved. Recycled plastic products could be made, people would take interest and see that they could make anything with their plastic waste. They could come and learn how to do it themselves and come out creating important pieces or parts that they need for their own project, household objects, and toys for their kids or children could come create master pieces of their own.

This project, has begun the setup of a workshop here in Ísafjörður at the high school. I did not know that was a real possibility until the end of week four, when Þórarinn said he wanted to turn this one room into a plastic recycling workshop. It is truly the perfect place for it. And now, since we have one of the machines, it could really work. We cleared out the excess items in the room, all that remains are two large tables, a sink, and an industrial oven. Fortunately, the schools kitchen is right above and has this nifty elevator shaft that connects to this room. A significant amount of plastic can be washed using the industrial dish washer in about 90 seconds, it is a tremendous time saver. We found large painter buckets and I labelled them accordingly to the different kinds of plastics. It would be nice to add shelves for the buckets, and get more buckets so plastic could be separated by color. The workshop also needs shelves to display completed recycled projects so if people, students, or workers walk by they could see them and be inspired to make something of their own. We would need to integrate some signs and large bins for plastic collection. And have some colorful signs recognizing this as a plastic recycling workspace. I have never seen so many curious people walk through the "unofficial" workshop and stop to take notice of what we were working on. Every person seemed genuinely interested and intrigued by this project.

If this is brought to an education system, it would be important for it to be very safe. This project was rushed in order to create the final product so the shredders current state is very dangerous. There are exposed wires, the motor fan moves very fast and is not covered, where the motor connects to the shredder is open, the hopper on the shredder is very short, and there is no cover on the shredder. All these things would need to be improved. First, we would need to have cable protection on the wires. Next, we need to have a cover on the fan that spins on the motor because that could hurt if a hand got in there since it spins fast. The connection between the motor and the shredder should be covered to avoid any fingers caught in there as well. And finally the shredder, it is tempting to put your hand into the hopper to help get the plastic to shred but that could tear a hand up pretty easily. The ideal hopper would be extended far enough above that even if an arm was reached all the way in, it would not come close to the blades. And a cover would be added to the top of the shredder to avoid plastic flakes that may fly out.

For future research, I think more development needs to be in building a workshop and/or curriculum around plastic pollution and how to recycle plastic on a small scale. I have so many ideas of how to integrate this into an education system. It would be great if students collected plastic in their household for one month and from that plastic created a recycled item out of it. It would be impactful, it would show that your plastic waste can be turned into something instead of ending up in landfills and polluting our environments. The point that needs to get across is that plastic is an incredibly versatile material but the amount of plastic being produced is so unsustainable and needs to be reeled back.

Another thought for the future would be integrating different colors and showing the limitless possible patterns that can be made with plastic. This would be beneficial in bringing to an education system, it would help spark more interest. The longer spread of time to collect plastic will allow for more plastic, more colors, and more variety. It will show that reusing plastic can be beautiful and plastic design can be manipulated in new ways with experimentation. This was not applicable here because of the short time frame and last minute plastic collecting.

7. Conclusion

I strongly believe that small scale recycling could be valuable and impactful if they are integrated into small communities. It frustrates me how much plastic is on this planet and plastic production is only continuing to increase. Plastic production should be decreasing, not increasing. Nothing is going to change the amount of plastic pollution unless it starts with small communities because the big scale recycling companies are only recycling 9% of plastic. If small recycling workshops can be set up, we can increase the amount of plastic being recycled and hopefully give people a new perspective on how much plastic they use in their lives. I feel people will feel compelled to start looking at their plastic consumption and see that their plastic waste can be turned into something useful for them. It could be anything they want it to be. The reason I wanted to do this project was to show people that you can make something that is useful and beneficial for many years to come. The lunchbox turned out better than I could have hoped for, it looks appealing and it works. This product represents reducing plastic waste on a small scale and shows that you can make something with purpose that will reduce your plastic usage.

8. References

About Harvey Mudd College. (n.d.). Retrieved May 14, 2018, from https://www.hmc.edu/about-hmc/

About the Hixon Center. (n.d.). Retrieved May 14, 2018, from https://www.hmc.edu/hcsed/about/

An underestimated threat: Land-based pollution with microplastics. (n.d.). Retrieved May 16, 2018, from https://www.sciencedaily.com/releases/2018/02/180205125728.htm

Doble, M. (2014). *Polymers in a Marine Environment*. Smithers Rapra.

Duis, K., & Coors, A. (2016). Microplastics in the aquatic and terrestrial environment: sources (with a specific focus on personal care products), fate and effects. *Environmental Sciences Europe*, *28*(1). https://doi.org/10.1186/s12302-015-0069-y

Fast Facts. (n.d.). Retrieved May 14, 2018, from https://www.hmc.edu/about-hmc/fast-facts/

Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. *Science Advances*, *3*(7), e1700782. https://doi.org/10.1126/sciadv.1700782

Hakkens, D. (2013). Precious Plastic. Retrieved April 20, 2018, from https://preciousplastic.com/en/index.html

Hopewell, J., Dvorak, R., & Kosior, E. (2009). Plastics recycling: challenges and opportunities. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*(1526), 2115–2126. https://doi.org/10.1098/rstb.2008.0311

Le Guern, C. (2018). Plastic Pollution. Retrieved April 20, 2018, from http://plastic-pollution.org/

Learning | What is Fusion 360. (n.d.). Retrieved May 17, 2018, from http://help.autodesk.com/view/fusion360/ENU/?guid=GUID-4E32611E-0790-479F-926A-66041C478864

Marine litter monitoring by Northern Fulmars in the Netherlands 1982-2003. (2012, September 28). Retrieved May 15, 2018, from https://www.wur.nl/en/Publication-details.htm?publicationId=publication-way-333334373732

Plastic Oceans. (n.d.). Retrieved May 21, 2018, from https://www.futureagenda.org/insight/plastic-oceans

Rethinking the future of plastics. (n.d.). Retrieved May 21, 2018, from http://dev.newplasticseconomy.org/report-2016

Science of Plastics. (2016, July 18). Retrieved May 15, 2018, from https://www.sciencehistory.org/science-of-plastics

Stacey, M. (2014). The FAB LAB Network: A Global Platform for Digital Invention, Education and Entrepreneurship. *Innovations: Technology, Governance, Globalization*, *9*(1–2), 221–238. https://doi.org/10.1162/inov_a_00211

van Franeker, J. A., & Law, K. L. (2015). Seabirds, gyres and global trends in plastic pollution. *Environmental Pollution*, *203*, 89–96. https://doi.org/10.1016/j.envpol.2015.02.034

What are microplastics? (n.d.). Retrieved May 15, 2018, from https://oceanservice.noaa.gov/facts/microplastics.html

Images Cited

https://commons.wikimedia.org/wiki/File:Recycling_pet.svg

https://en.wikipedia.org/wiki/High-density_polyethylene

https://commons.wikimedia.org/wiki/File:Plastic-recyc-03.svg

https://www.highspeedtraining.co.uk/hub/plastic-packaging-symbols/

https://commons.wikimedia.org/wiki/File:Plastic-recyc-05.svg

https://en.wikipedia.org/wiki/File:Resin-identification-code-6-PS.svg

https://www.quora.com/What-are-different-types-of-plastic-grades

http://www.fabfoundation.org/index.php/fab-labs/index.html

https://davehakkens.nl/preciousplastic/making-plastic-precious/

https://commons.wikimedia.org/wiki/File:Precious_Plastic_Logo.png